OPEN-FILE REPORT 97-11

SEISMIC HAZARD EVALUATION OF THE NEWHALL 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

1997

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

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PREFACE

With the increasing public concern about the potential for destructive earthquakes in northern and southern California, the State Legislature passed the Seismic Hazards Mapping Act in 1990. The purpose of the Act is to protect the public from the effects of strong ground shaking, liquefaction, landslides or other ground failure, and other hazards caused by earthquakes. The program and actions mandated by the Seismic Hazards Mapping Act closely resemble those of the Alquist-Priolo Earthquake Fault Zoning Act (which addresses only surface fault-rupture hazards) and are outlined below:

1. **The State Geologist** is required to delineate the various "seismic hazard zones."

2. **Cities and Counties**, or other local permitting authorities, must regulate certain development "projects" within the zones. They must withhold the development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans.

3. **The State Mining and Geology Board (SMGB)** provides additional regulations, policies, and criteria to guide cities and counties in their implementation of the law. The SMGB also provides criteria for preparation of the Seismic Hazard Zone Maps (Web site http://www.consrv.ca.gov/dmg/shezp/zoneguid/) and for evaluating and mitigating seismic hazards.

4. **Sellers (and their agents)** of real property within a mapped hazard zone must disclose at the time of sale that the property lies within such a zone.

As stated above, the Act directs the State Geologist, through the Division of Mines and Geology (DMG) to delineate seismic hazard zones. Delineation of seismic hazard zones is conducted under criteria established by the Seismic Hazards Mapping Act Advisory Committee and its Working Groups and adopted by the California SMGB.

The Official Seismic Hazard Zone Maps, released by DMG, which depict zones of required investigation for liquefaction and/or earthquake-induced landslides, are available from:

BPS Reprographic Services
149 Second Street
San Francisco, California 94105
(415) 512-6550

Seismic Hazard Evaluation Reports, released as Open-File Reports (OFR), summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These Open-File Reports are available for reference at DMG offices in Sacramento, San Francisco, and Los Angeles. Copies of the reports may be purchased at the Sacramento, Los Angeles, and San Francisco offices. In addition, the Sacramento office offers prepaid mail order sales for all DMG OFRs. **NOTE: The Open-File Reports are not available through BPS Reprographic Services.**

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Seismic Hazard Evaluation Reports and additional information on seismic hazard zone mapping in California are available on the Division of Mines and Geology's Internet homepage:
http://www.consrv.ca.gov/dmg/shezp/

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

The Act also directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria provide detailed standards for mapping regional liquefaction hazards. They also directed DMG to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that the 1) process for zoning liquefaction hazards remain unchanged and that 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

This Seismic Hazard Evaluation Report summarizes the development of the hazard zone map for each area. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, historic high-water-table information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10% probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils and earthquake-induced landslides in the Newhall 7.5-minute Quadrangle (scale 1:24,000).

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Newhall 7.5-Minute Quadrangle, Los AngelesCounty, California

By
Wayne D. Haydon and Allan G. Barrows

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Newhall 7.5-minute Quadrangle (scale 1:24,000). This section and Section 2 addressing earthquake-induced landslides, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazards zone mapping in California can be accessed on DMG's Internet homepage:
http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Liquefaction-induced ground failure has historically been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes, significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated granular sediments within the upper 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern California, most notably in some densely populated valley regions and alluviated floodplains. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region in general, as well as in the Newhall Quadrangle.

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils is generally confined to areas covered by Quaternary sedimentary deposits. Such areas consist mainly of alluviated valleys, floodplains, and canyon regions. The evaluation is based on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth data, most of which are gathered from a variety of sources. The quality of the data used varies. Although selection of data used in this evaluation was rigorous, the state of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth and thickness of liquefiable sediments, depth to ground water, rate of drainage, slope gradient, proximity to free-face conditions, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to determine the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction potential, opportunity, susceptibility, and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The Newhall Quadrangle covers approximately 62 square miles of land in west-central Los Angeles County. The center of the quadrangle lies about 30 miles northwest of the Los Angeles Civic Center. The City of Santa Clarita, which incorporates the communities of Newhall, Saugus, Valencia, and Canyon Country, covers the southeastern and east central parts of the quadrangle. The remainder of the area is comprised of unincorporated county land. A small part of the northeastern corner of the map lies within the Angeles National Forest. The primary transportation routes follow the valleys of the Santa Clara River and its tributaries. Access is provided from the north and the south via Interstate Highway 5, from the east via Soledad Canyon Road and Bouquet Canyon Road, and from the west via State Highway 126.

A variety of mountainous and lowland terrains characterizes the physiography of the quadrangle. The deeply dissected, mountainous topography that separates the major canyons includes: in the southwest quarter, portions of the northern Santa Susana Mountains; in the southeastern corner, a small northwesternmost extension of the San Gabriel Mountains; and, north of the Santa Clara River Valley is a region of rugged, chaparral-covered rocky terrain.

The Santa Clara River flows across the center of the quadrangle from east to west. Major tributaries include: the South Fork of the Santa Clara River along with its branches, Newhall Creek and Placerita Creek, which joins the main stream near Bouquet Junction; Castaic Creek, which joins the river near Castaic Junction; and the unnamed streams that flow southward into the Santa Clara River from Bouquet, Dry, and San Francisquito canyons.

Residential and commercial development has replaced agricultural and grazing land uses within the area in recent decades. Modern development is characterized by mass grading of the hillside areas at a large scale, especially north of the Santa Clara River and west of Interstate 5. The remainder of the area is largely unoccupied, although oil fields, agricultural activities, small ranches, and parklands are scattered across the quadrangle.

GEOLOGIC CONDITIONS

Structural and Depositional Setting

The Newhall Quadrangle lies within the Transverse Ranges geomorphic province of southern California. This province is characterized by a complex series of mountain ranges and valleys with dominant east-west trends. The features are related to an underlying structural framework of aligned anticlines, synclines, and reverse fault systems. A major structural element of the western Transverse Ranges, the easternmost extent of the Ventura Basin, lies within the Newhall Quadrangle. An immense thickness of marine sedimentary rocks accumulated within the

Ventura Basin in late Cenozoic time. The axis of the Ventura Basin trends east-west and coincides approximately with the trend of the Santa Clara River (Winterer and Durham, 1962).

The late Miocene to Pliocene marine and continental sedimentary rocks, which were deposited within the Ventura Basin, are exposed throughout the upland terrain in the Newhall Quadrangle. Terrace deposits (Winterer and Durham, 1962; Yerkes and Campbell, 1995) or “older dissected surficial sediments” (Dibblee, 1996) covers substantial portions of the southern half of the quadrangle. Quaternary alluvium is widespread in the canyon bottoms and valleys of the streams that are tributary to the Santa Clara River.

Surface Geology

The digital geologic map of Yerkes and Campbell (1995) was used to evaluate the geologic units of the study area for liquefaction. Other geologic maps reviewed for this project include Winterer and Durham (1962), Weber (1982), Smith (1984), and Treiman (1986; 1987). Only the types of geologic units that are generally susceptible to liquefaction were evaluated. Such units include the Quaternary alluvial and young fluvial sedimentary (flatland) deposits and artificial fill. The geologic map of Yerkes and Campbell (1995) provided the most detail in the mapping of the Quaternary fluvial and alluvial flatland sedimentary deposits. However, the mapping of the Quaternary deposits was inconsistent across the map and was not considered detailed or accurate enough to use for evaluating the liquefaction susceptibility of the different Quaternary units exposed in the Newhall Quadrangle. Therefore, a reconnaissance geologic map for use in this project was prepared that focused upon differentiating the Quaternary fluvial and alluvial flatland sedimentary deposits. The mapping was based on the evaluation of flatland geomorphology, aerial photograph interpretation, examination of soil survey maps (Woodruff and others, 1966), review of subsurface borehole logs and field reconnaissance. The reconnaissance geologic map differs from the map of Yerkes and Campbell (1995), in that the entire bedrock-alluvium contact was remapped in greater detail and some of the unit designations were reassigned, based upon a reevaluation of the age of each unit or its geomorphic expression. The geologic units were also grouped more consistently. Plate 1.1 presents a map depicting the portion of the Newhall Quadrangle underlain by Quaternary alluvial and young fluvial sedimentary (flatland) deposits and artificial fill that are interpreted as being generally susceptible to liquefaction and were evaluated in this investigation.

Quaternary fluvial and alluvial flatland sedimentary deposits were mapped in the main and tributary valleys and canyons of the Santa Clara River, Castaic Creek, South Fork Santa Clara River, Soledad Canyon, Bouquet Canyon, Pico Canyon, San Francisquito Canyon, Dry Canyon, Haskell Canyon, Gavin Canyon, the unnamed valley east of Gavin Canyon, Placerita Canyon, Quigley Canyon, Newhall Creek, and Potrero Canyon and other unnamed canyons. Most of the soil series developed on the deposits, interpreted in the mapping for this project as late Holocene fluvial and alluvial units, are those generally considered to overlie Holocene geologic units (Tinsley and Fumal, 1985).

Active washes were mapped along the incised channels in the main and tributary canyons and valleys. The washes are partially filled with sand and gravel deposited as bedload by wet-season stream flow. These washes are incised into the late Holocene fluvial deposits of the valley floors. Active fluvial and fan deposits were mapped as small, planar or convex-outward, fan shaped, non-incised or slightly incised deposits, generally in the smaller tributary drainages. Included with the fans are small areas of slope wash and colluvium which were not mapped separately for this project. On the Yerkes and Campbell (1995) map, both active washes and fluvial and fan deposits were generally mapped as “undifferentiated Quaternary alluvium” (Qal), except in the northeast quarter of the quadrangle where slope wash (Qsw) was differentiated.

Late Holocene fluvial deposits were mapped along the planar, slightly to moderately incised, gently downstream-sloping floors of all the main and many of the tributary canyons and valleys. Late Holocene alluvial terraces were mapped between the Santa Clara River and the South Fork Santa Clara River just upstream of the confluence of the Santa Clara River with the South Fork of the Santa Clara River and on the western margin of Castaic Valley in the alluvial flat north of Hasley Canyon. Late Holocene alluvial fans were mapped as the convex-outward, fan-shaped deposits that slope toward the main trunk stream and valley floor. These deposits form individual fans or coalesce to form alluvial aprons along the margins of the main canyons and valleys and emanate from some of the tributary canyons. The alluviated flatlands upslope from the fans in the tributary valleys were mapped as active or late Holocene fluvial deposits. These deposits were identified: in Castaic Valley near Castaic and emanating from Villa Canyon and Wayside Canyon; on the northern and southern margins of the Santa Clara River Valley emanating from the tributary canyons between San Francisquito Canyon and Castaic Valley; alternately on the west and east margins of San Francisquito Canyon; along the eastern margin of Dry Canyon; and along the southern margin of Pico Canyon west of Highway 5. On the Yerkes and Campbell (1995) map the late Holocene fluvial deposits and young alluvial terrace deposits and fans were generally mapped as undifferentiated Quaternary alluvium (Qal), except in Castaic Valley were the terrace deposits and fans were assigned to Holocene to Pleistocene aged older alluvium (Qao) and in the northeast quarter of the study area where the alluvium in the main valley was differentiated from alluvium in the upland tributary valleys (Qal1; Qal2), and the fans and aprons were not differentiated.

Where water levels are high, younger Holocene fluvial and alluvial deposits are generally considered to have moderate to high liquefaction susceptibility (Youd and Perkins, 1987).

Terrace deposits (Qto) and older alluvium (Qao) were mapped on erosional surfaces in the upland areas on the map of Yerkes and Campbell (1995) and during the detailed mapping for this project.

Artificial fill was mapped, both by Yerkes and Campbell (1995) and during the mapping for this project, in Bouquet Canyon, Dry Canyon and Haskell Canyon. The fill is generally thin and was placed during the grading for relatively recent, large residential and commercial developments.

Subsurface Geology and Geotechnical Characteristics

Information on the subsurface geology and geotechnical characteristics of the flatland deposits was obtained from borehole logs collected from reports on work done in the study area. About

400 borehole logs were collected from the files of the Los Angeles County Department of Public Works; California Regional Water Quality Control Board, Los Angeles Region; and private consultants. Evaluation of borehole logs and reconnaissance mapping of the younger deposits indicate that the fluvial and alluvial deposits consist primarily of coarse-grained sediments, mostly sand, silty sand and gravel, with interbeds of silt and clay. These deposits are discussed below, grouped into three locales or physiographic environments, based on the relative proportions of the coarser-grained sediment types (sand, silty sand, and gravel) to the finer-grained material (silt and clay).

Data from borehole logs were entered into the DMG GIS database. Locations of all exploratory boreholes considered in this investigation are shown on Plate 1.2. Construction of cross sections from the borehole logs, using the GIS, enabled the correlation of soil types from one borehole to another and outlining of areas of similar soils.

Castaic Valley and Placerita Canyon

Along the main trunk of Castaic Creek in the Castaic Valley, from the northern boundary of the quadrangle to just north of Castaic Junction (Highway 5/126 interchange), and in Placerita Canyon, the fluvial deposits consist primarily of brown, gray and gray-brown poorly graded medium to coarse sand and well-graded fine to coarse sand, both with gravel and cobbles. In the Castaic Valley, this material also contains discontinuous interbeds of: brown or gray, silty sand with fine and/or fine to medium sand, occasionally with gravel and cobbles; and brown, fine to coarse gravel with sand or silt, and gray-rown or brown sandy silt.

The sand deposits, with incorporated gravel and cobbles, in the Castaic Valley are generally described as medium dense to very dense with SPT field N values commonly from about 40 to over 100, although some are as low as 10 to 30. However, as described in the section on Quantitative Liquefaction Analysis, the gravel clasts probably cause many of the SPT field N values to be too high. The density of the sand deposits in Placerita Canyon was not described in the logs and no SPT N values for these deposits were identified. In both Castaic Valley and Placerita Canyon, moisture contents are generally less than 15%. Locally, moisture contents are as high as 20%. Dry unit weights are generally 100 to 120 pounds per cubic foot (pcf) with a range in values from about 90 pcf to about 130 pcf. No geotechnical data were found for the gravel interbeds.

The silty sands were generally described as medium dense to dense with SPT field N values ranging from about 10 to 30. Moisture contents are generally less than 15%, with some values as high as nearly 30%. Dry unit weights are generally about 90 to 110 pcf although values range from about 65 pcf to about 135 pcf.

Based on the age and depositional environment of this deposit the sand, silty sand and gravel are interpreted as being loose to medium dense.

The silts are generally described as dense, firm or medium stiff with practically no SPT N values recorded. The few moisture contents found are generally about 15 to 20% and the few dry unit weights are generally between 85 and 90 pcf with one value as high as about 120 pcf.

Santa Clara River Valley, South Fork Santa Clara River Valley and associated larger alluvial canyons and valleys

Along the Santa Clara River Valley south of Castaic Junction, the South Fork Santa Clara River Valley, Bouquet Canyon, Soledad Canyon, the mouth of Dry Canyon, Pico Canyon, Gavin Canyon and the south half of San Francisquito Canyon, the fluvial and alluvial fan deposits consist of complexly interbedded: brown, gray-brown and red-brown silty and, occasionally, clayey, fine to medium and fine to coarse sand with little to some gravel; less brown and gray-brown poorly graded fine to medium and medium to very coarse sand and well-graded fine to very coarse sand, both with no to some gravel and cobbles; and brown sandy silt, silty clay and, occasionally, clay, both with no to little fine to medium sand. The presence and amount of sand lenses in the silt-sand strata and the gravel content in the sand units generally increases with depth. Within 30 to 40 feet of the surface, the fluvial deposits consist primarily of silty sand and the gravel content is generally described as none to few. At depths below 30 to 40 feet, the fluvial deposits consist primarily of sand and the gravel content is described as no to some gravel with cobbles. The two primary types of coarse-grained deposits, silty sand and sand, and deposits with similar gravel content are discontinuous and show little correlation between boreholes. The fine-grained deposits are more laterally continuous over various distances and can sometimes be traced for up to a mile. These fluvial deposits along the Santa Clara River Valley have significantly less gravel, more silty sand, and a greater percentage of and more continuous silt and silty clay interbeds than the fluvial deposits in Castaic Valley.

The silty sands and sands with no to few gravel clasts that are shallower than about 30 to 40 feet are generally described as medium dense to dense. The SPT field N values in these deposits are generally less than 30, however, locally SPT field N values greater than 50 blows do occur in these deposits. The silty sands and sands with no to some gravel deeper than 30 to 40 feet are generally described as dense with SPT field N values generally greater than 30, with a significant number showing values greater than 50 blows. In both the shallow and deep deposits, the silty sands and sands with gravel are more often described as dense or very dense, whereas the deposits without gravel are more often described as medium dense to dense, often regardless of the SPT N value measured. This suggests that the presence of gravel in a deposit results in a density description on the logs that often overestimates the density of the deposit, making these descriptions in units without measured SPT N values suspect. Additionally, the higher SPT N values in some of the soils are likely to be due to the gravel content. However, silty sands and sand deposits without gravel and with high SPT field N values were identified. This unit is interpreted to consist of interbedded moderately dense to dense silty sands and sands with a greater proportion of moderately dense deposits above 30 to 40 feet and a greater proportion of dense deposits below 30 to 40 feet.

Moisture contents in the silty sands and sands are generally less than 30%. Dry unit weights are generally about 80 to 110 pcf in the silty sands and about 95 to 130 pcf in the sands. The silts and silty clays are generally described as firm, medium stiff or stiff. SPT field N values generally range between 9 and 30, with SPT field N values as low as 3 and as high as 100 blows recorded. Moisture contents are generally about 10 to 30%.

Upland alluvial valleys and alluvial fans flanking the larger and smaller alluvial canyons

In Potrero Canyon, the alluvial terraces, alluvial fans and tributary upland alluvial valleys, which are within or flank the larger canyons, the fluvial and alluvial deposits generally consist of complexly interbedded: light-brown, brown and gray-brown, silty fine to medium and fine to coarse sand, generally with no to little gravel and/or cobbles; light-brown, brown and gray-brown poorly graded fine to medium sand or well-graded fine to coarse sand with little to some gravel or cobbles; and thick to thin, discontinuous interbeds of brown sandy silt with no to few gravel.

These deposits are generally similar to the shallow deposits of the Santa Clara River Valley and associated larger alluvial canyons and valleys. However, they do contain more gravel, more silty sand, and a smaller percentage of and less continuous silt and clay interbeds than the shallow fluvial deposits in the Santa Clara River Valley.

The nature of the fluvial and alluvial deposits varies throughout the study area. The alluvial fans that flank the margins of Castaic Valley consist primarily of nearly equal amounts of sand and silty sand and contain less gravel, more fine sand and more silty sand than the fluvial deposits of the main trunk of the valley. The upland alluvial valleys, upstream of the alluvial fans flanking Castaic Valley, contain more gravel, and more silty sand than the fan deposits. In the alluvial terrace mapped on the western margin of Castaic Valley, in the alluvial flat north of Hasley Canyon, the gravel content appears to increase with depth in the sands. These deposits contain more silt beds and a similar gravel content in the deeper sands compared to the fluvial deposits along the main trunk of Castaic Valley. In the upland alluviated valleys southwest of the Santa Clara River Valley the alluvial deposits also include red-brown, silty sand and clay interbeds.

In the alluvial fans that flank Castaic Valley the sands and silty sands are generally described as medium dense and, rarely, dense with SPT field N values of less than 10 in the sands. In the silty sands, SPT field N values range from about 10 to 30, with a few values ranging from as low as 5 to as high as about 80 blows. Despite the gravel clasts, the N values appear reasonable for the age and depositional environment of this unit.

In the alluvial terrace mapped on the western margin of Castaic Valley, the density of the sands and silty sands was not described in the logs. SPT field N values in the sands range from 18 to 40 in the shallow deposits, which have lower gravel contents, and up to over 100 blows in the deeper deposits, which have a higher gravel content. The SPT field N values in the deeper deposits are probably too high due to the gravel. No SPT N values were identified in the silty sands. The SPT field N values in the shallower deposits appear reasonable for the age and depositional environment of this unit.

The density of the sands and silty sands in the upland alluvial valleys, upstream of the alluvial fans flanking Castaic Valley, was not described and the limited number of SPT field N values obtained from the silty sands yield results where about half are less than 30 and half are greater than 30, with values as high as 75 blows with only one SPT field N value of 42 identified in sand deposits. The SPT field N values greater than 30 are interpreted as being too high due to the gravel. The SPT field N values of less than 30 in the shallower deposits appear reasonable for the age and depositional environment of this unit.

In the upland alluviated valleys southwest of the Santa Clara River Valley, the silty sands and sands are generally described mostly as medium dense and dense. No SPT field N values for these units were identified. However, the gravel content of these deposits has likely resulted in descriptions that overestimate the density of the deposits, making these descriptions suspect. Based on the age and depositional environment of these deposits, the unit is interpreted as being loose to medium dense.

Moisture contents in the sands and silty sands are generally less than 10%, with a few values as high about 15%. Dry unit weights are generally 110 to 125 pcf with values ranging from about 95 pcf to about 130 pcf. In the alluvial terrace mapped on the western margin of Castaic Valley, dry unit weights are generally about 95 to 115 pcf in the shallow deposits and between 120 and 125 pcf in the deeper deposits.

The moisture content, dry unit weight and density of the silt and clays were not described and no SPT field N values were identified for the units in the Santa Clara River Valley, Bouquet Canyon, and Soledad Canyon. In the upland alluvial valleys, upstream of the alluvial fans flanking Castaic Valley, the alluvial terrace mapped on the western margin of Castaic Valley, and the tributary upland alluvial valleys of Soledad Canyon, the density of the silts is generally described as stiff or firm with SPT field N values generally less than 8 with a few values of up to 15 identified. Moisture contents are generally less than 15% with a few values up to 25%. Dry unit weights are generally about 106 to 115 pcf with some values as high as about 130 pcf.

GROUND-WATER CONDITIONS

Liquefaction hazard mapping focuses on areas historically characterized by ground-water depths of 40 feet or less. Accordingly, ground-water conditions were investigated in the Newhall Quadrangle to evaluate the depth to saturated sediments. Saturated conditions reduce the normal effective stress acting on loose, near-surface sandy deposits, thereby increasing the likelihood of liquefaction (Youd, 1973). Ground-water depth data were obtained from published ground-water investigations (Robson, 1972) that summarized ground-water conditions in the study area for the years 1945 to 1967, annual maps of the ground-water elevation contour in the alluvial valley deposits prepared by the Los Angeles County Department of Public Works, Hydraulic/Water Conservation Division (LACDPW) for the years 1945 through 1995 (LACDPW, 1995), and from the collected geotechnical and environmental borehole logs. The evaluation was based on first-encountered water levels encountered in the boreholes and selected water wells.

Interpretation of data from Robson (1972) and LACDPW (1995) indicates that the 1945 ground-water elevation contour map of the alluvial valley aquifer represents the shallowest recorded ground-water levels for most, but not all, of the study area. In some parts of the study area the shallowest recorded ground-water levels occurred in other years. A ground-water elevation contour map of the shallowest recorded water levels for the study area was compiled from the

1945 ground-water elevation contour map of Robson (1972) and LACDPW ground-water contour maps from various years that represented the shallowest ground-water identified in parts of the study area. The regions of the study area and the year of the ground-water elevation contour map used to compile the ground-water map are as follows: in Haskell Canyon and Bouquet Canyon from Haskell Canyon to the eastern edge of the study area, 1983; in San Francisquito Canyon, 1993; in Pico Canyon, 1947; in Gavin Canyon, 1948; in the unnamed canyon east of Gavin Canyon, 1973; in Placerita Canyon, 1995; along Newhall Creek, 1952; and in the canyon west of Newhall Creek, 1955. The depth to the shallowest recorded ground-water map is presented on Plate 1.2.

The depth-to-ground water contour map (Plate 1.2) was prepared by comparing the compiled shallowest ground-water elevations with the ground surface elevations. However, several modifications had to be made to the depth-to-ground water contour map to fill gaps and correct generalizations in the data and to make this map more accurately reflect the most likely ground-water conditions. Although flowing artesian ground-water conditions were identified in Castaic Valley and the Santa Clara River Valley, the depth to ground water in these areas was taken as 0 feet. Comparison of the Quaternary geologic map (Plate 1.1) and ground-water contour map (Plate 1.2) indicates that the monitored wells are mostly in the planar and nearly level fluvial valley deposits underlying the central valley floor and not in the sloping alluvial fans that flank the fluvial deposits, yet the ground-water contours have been drawn in the past across the entire valley, across both the fluvial and the fan deposits. Therefore, the wells accurately represent ground-water conditions in the fluvial deposits but not the fans. This makes it appear that the cross-valley ground-water surface is level under both the fluvial and the fan deposits and does not rise to follow the topography of the sloping fan surfaces. This implies that the fans and upstream smaller alluvial valleys are not contributing ground water to the larger valleys and that ground-water levels under the fans are considerably deeper than under the adjacent fluvial deposits. Such a ground-water condition is considered very unlikely.

Accordingly, the ground-water contours that cross the valley from the fluvial valley floor to the flanking fans are considered suspect where they cross the fans. To alleviate this problem, the depth to ground water underlying the fans flanking the valleys was interpreted uniformly as the depth to ground water identified at the distal edge of the fan, along the geologic contact between the fluvial and fan deposits. This condition was identified along Castaic Valley, San Francisquito Canyon, Dry Canyon and the Santa Clara River Valley. The applicability of this method of accommodating the special aspects of ground-water levels in fans was evaluated by noting the depth to ground water in boreholes identified on the fans, adjusting the depths for the relative approximate differences in ground-water depth between the year the borehole was drilled and the year of data used to compile the depth-to-ground water map (Plate 1.2), and then comparing the adjusted ground-water level in the borehole to depth-to-ground water map. The analysis indicates that this method does a generally good job of approximating the actual depth to ground water within the alluvial fans flanking the valley floors.

Inspection of the ground-water contour map indicates that in Dry Canyon the depth to ground water approaches 65 feet about half the way up the canyon north of the Santa Clara River Valley. This deep ground-water figure is peculiar, because similar canyons to the west, San Francisquito

Canyon, and to the east, Haskell Canyon, have relatively shallow ground water. This deep measurement to ground water may be the result of the monitored well having been partially completed into the Saugus Formation, identified as having deeper ground water (Robson, 1972), underlying the valley alluvium and the flow of ground water in the well from the alluvium to the Saugus, and the subsequent drawdown in the well. Therefore, the depth to ground water in the liquefaction analysis for Dry Canyon was taken as 30 feet, a depth similar to that in Haskell Canyon.

Ground-water information was generally lacking in the many small alluvial valleys that are tributary to the main valleys of Castaic Valley, Santa Clara River, South Fork Santa Clara River, Soledad Canyon, Bouquet Canyon, and Pico Canyon. These tributary canyons merge with the trunk valleys either directly onto the fluvial deposits of the valley floor or onto the alluvial fans that flank the valleys. Ground-water information is also generally lacking in the northern halves of San Francisquito Canyon, Dry Canyon and Haskell Canyon. The depth to ground water for the northern half of San Francisquito Canyon, Dry Canyon, and Haskell Canyon was taken as the northernmost depth-to-ground-water contour identified in each of the valleys, except, as noted above, for Dry Canyon. The depth to ground water for the small tributary canyons was taken as the depth to ground water identified or interpreted at the mouth of the tributary canyon where the canyon merges with either the main valley or the alluvial fans. In the southern portion of the Newhall Quadrangle, where ground water in the main valleys is generally deep, the depth to ground water in the tributary canyons and the western end of Pico Canyon was taken as 20 or 30 feet instead of the deeper value in the main valley. A shallower ground-water depth was assigned because the alluvial portion of these canyons are not areally extensive, yet they drain moderately large watersheds, and, therefore, it seems likely that some of the alluvium of these canyon can become saturated temporarily following extended precipitation. The depth to ground water in Potrero Canyon and the unnamed canyon just to the north was taken as 25 feet based on ground-water data identified in geotechnical boreholes drilled to the west of the study area.

The historically shallowest ground-water level ranges from very shallow to deep across the study area with the shallowest water occurring in the north and the deepest water occurring in the south. In Castaic Valley, Santa Clara River, San Francisquito Canyon, Bouquet Canyon and Soledad Canyon the depth to ground water is generally less than 15 feet, with extensive areas of less than 5 feet to ground water and limited areas of 20 feet. In Bouquet Canyon the depth to ground water deepens to 20 feet at the mouth of Haskell Canyon. Water levels then deepen to 25 feet from Haskell Canyon to the eastern edge of the study area. In Haskell Canyon, the depth to ground water at the canyon mouth is 25 feet. The ground-water levels deepen to the north to a maximum of 40 feet, then shallow to 25 feet.

Ground-water levels south of the Santa Clara River, in the South Fork Santa Clara River, deepen toward the south, reaching a depth of 70 feet in Pico Canyon. In Gavin Canyon (not labeled on the map, although it extends into the Newhall Quadrangle from the Oat Mountain Quadrangle) the depth to ground water at the southern edge of the study area is less than 40 feet but to the north it deepens to 50 feet at the canyon mouth. In the unnamed valley east of Gavin Canyon, the depth to ground water is 75 feet at the southern edge of the study area and, to the north, at the canyon mouth it deepens to 100 feet. The depth to ground water in the Newhall Creek Valley is 75 feet at the southern edge of the study area and, to the north, ground water is at 85 feet. In Placerita Canyon, the depth to ground water is between 50 and 60 feet west of the tributary Quigley Canyon, whereas to the east of Quigley Canyon the depth to ground water shallows to 30 feet at the eastern edge of the study area. In Quigley Canyon the depth is interpreted to be 40 feet or less. The depth to ground water in the tributary canyons and the western end of Pico Canyon was taken as 20 or 30 feet. The depth to ground water in Potrero Canyon and the unnamed canyon just to the north was taken as 25 feet. The depth to ground water in Dry Canyon was taken as 30 feet, as stated above.

PART II

EVALUATING LIQUEFACTION POTENTIAL

Liquefaction occurs in water-saturated sediments during moderate to great earthquakes. Liquefied sediments are characterized by a loss of strength and may fail, causing damage to buildings, bridges, and other such structures. A number of methods for mapping liquefaction hazard have been proposed; Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of susceptibility units, and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce liquefaction potential. Liquefaction susceptibility is a function of the capacity of sediments to resist liquefaction and liquefaction opportunity is a function of the seismic ground shaking intensity. The application of the Seed Simplified Procedure (Seed and Idriss, 1971) for evaluating liquefaction potential allows a quantitative characterization of susceptibility of geologic units. Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for mapping liquefaction hazards in the Los Angeles region. The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985), combining geotechnical data analyses, and geologic and hydrologic mapping, but follows criteria adopted by the California State Mining and Geology Board (in press).

LIQUEFACTION OPPORTUNITY

According to the criteria adopted by the California State Mining and Geology Board (in press), liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for ground shaking strong enough to generate liquefaction. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10% probability of exceedance over a 50-year period. The earthquake magnitude is the magnitude that contributes most to the acceleration.

For the Newhall Quadrangle, a peak acceleration of 0.60 g resulting from an earthquake of magnitude 7.0 was used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10% in 50-year hazard level (Petersen and others, 1996) and Cramer and Petersen (1996), respectively. See the ground motion portion (Section 3) of this report for further details.

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of soils to loss of strength when subjected to ground shaking. Primarily, physical properties and conditions of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance. These properties and conditions are correlated with geologic age and environment of deposition. With increasing age of a deposit, relative density may increase through cementation of the particles or the increase in thickness of the overburden sediments. Grain size characteristics of a soil also influence susceptibility to liquefaction. Sands are more susceptible than silts or gravels, although silts of low plasticity are treated as liquefiable in this investigation. Cohesive soils are generally not considered susceptible to liquefaction. Such soils may be vulnerable to strength loss with remolding and represent a hazard that is not addressed in this investigation. Soil characteristics and processes that result in lower liquefaction susceptibility generally result in higher penetration resistances to the soil sampler. Different blow count corrections are used for silty sand and nonplastic silt than for clean sand (Seed and others, 1985). Therefore, blow count or cone penetrometer values are a useful indicator of liquefaction susceptibility.

Saturation is required for liquefaction, and the liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (more likely to liquefy). Soils that lack resistance (susceptible soils) are typically saturated, loose sandy sediments. Soils resistant to liquefaction include all soil types that are dry or sufficiently dense.

DMG's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil-property and soil-condition factors such as type, age, texture, color, and consistency, along with historic depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, findings can be related to the map units. DMG's qualitative susceptible soil inventory is summarized below.

The susceptibility of a deposit to liquefaction during future earthquakes was characterized by grouping deposits into high, moderate, low, and very low susceptibility categories based on depth to ground water, type of sediment, texture, consistency, and the quantitative liquefaction analyses. Pre-Quaternary, bedrock geologic units are considered to have very low susceptibility.

The liquefaction analyses identified liquefiable strata in greater than 90% of the boreholes analyzed in areas underlain by late Holocene fluvial and alluvial deposits that did not contain gravel. On the basis of the liquefaction analysis and re-analysis of the subsurface soils encountered in the boreholes and the interpreted Quaternary geology, the fluvial and alluvial flatland valley and fan deposits in the Newhall Quadrangle with an historic shallow ground-water depth of less than 40 feet are considered to meet the liquefaction susceptibility zoning criteria under the applied ground motion. All the geologic units either were shown to contain liquefiable sediments by the liquefaction analysis, or were judged to potentially contain liquefiable sediments by correlation with adjacent units or similar units in other portions of the study area or because such units were of similar age and mode of deposition. Sufficient geotechnical data to fully analyze all the units in all portions of the study area were simply not available.

The Quaternary terrace deposits mapped in the uplands of the study area are considered to be too consolidated and be above the regional ground-water table to meet the liquefaction susceptibility zoning criteria under the applied ground motion.

Quantitative Liquefaction Analysis

DMG performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; Seed and others, 1985; National Research Council, 1985; Seed and Harder, 1990; Youd and Idriss, 1997). This procedure calculates soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR) based on standard penetration test (SPT) results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The factor of safety (FS) relative to liquefaction is: FS=CRR/CSR. FS, therefore, is a quantitative measure of liquefaction potential. DMG uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the "trigger" for liquefaction, for a site specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site related structures. For a regional assessment DMG normally has a range of FS that results from the liquefaction analyses. The DMG liquefaction analysis program calculates an FS at each sample that has blow counts. The lowest FS in each borehole is used for that location. These FS vary in reliability according to the quality of the geotechnical data. These FS as well as other considerations such as slope, free face conditions, and thickness and depth of potentially liquefiable soil are evaluated in order to construct liquefaction potential maps, which then directly translate to Zones of Required Investigation**.**

Of the approximately 400 geotechnical borehole logs reviewed in this study (Plate 1.2), fewer than 85 include blow-count data from SPT's or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2 1/2-inch inside diameter ring samplers, were translated to SPT-equivalent values if reasonable factors could be used in conversion calculations. The reliability of the SPT-equivalent values varies. Therefore, they are weighted and used in a more qualitative manner. Few borehole logs, however, include all of the information (soil density, moisture content, sieve analysis, etc) required for an ideal Seed Simplified Analysis. For boreholes having acceptable penetration tests, liquefaction analysis is performed using logged density, moisture, and sieve test values or using average test values of similar materials.

The liquefaction evaluation procedures where developed primarily for clean sands and silty sands. Results depend greatly on the accurate evaluation of the in-situ density of soils as measured by the number (N) of soil penetration blow counts using a soil penetration test (SPT) sampler or a cone-penetrometer test (CPT). However, many of the Holocene fluvial and alluvial deposits in the Newhall Quadrangle contain a significant gravel component. In the past, gravelly soils were considered not to be susceptible to liquefaction because the high permeability of such soils would allow the dissipation of pore water pressures before liquefaction could occur. However, liquefaction in gravelly soils has been observed during many earthquakes and recent laboratory studies have shown that certain gravelly soils are susceptible to liquefaction.

Field and laboratory studies regarding the liquefaction susceptibility of gravelly sands (Sy and others, 1996: Budiman and Mohammadi, 1996; Harder and Seed, 1986; Ishihara, 1995; and Evans and Zhou, 1995) indicate that *sandy* and *silty* gravels have significantly lower permeabilities than *clean* gravels and, therefore, do not dissipate excess pore pressures quickly enough to prevent liquefaction. Boundary drainage conditions were found to be important. For example, the presence of an impervious surface layer can impede drainage leading to liquefaction of underlying gravelly soils.

Liquefaction susceptibility is dependent on the gravel content of the soil, the presence of a liquefiable sand lens in the gravelly unit, and, in matrix supported gravels, on the density of the matrix sand. The liquefaction susceptibility of sand and gravel composites may decrease considerably with increasing gravel content. Gravel contents of less than 20 to 25% were found not to decrease liquefaction susceptibility and may increase susceptibility, whereas deposits with 40 to 60% gravel and a moderately dense sand matrix had the liquefaction susceptibility of dense sand. In general, loose to medium dense gravelly sands, with equivalent sand SPT N values less than about 20 are susceptible to liquefaction.

SPT- or CPT-derived density measurements in gravelly soils are unreliable and generally too high because the gravel clasts are too large to fit into the sampler or they bridge the opening of the sampler. The sampler tends to bounce on the clasts in such gravels. Field methods developed to evaluate the liquefaction susceptibility of gravelly soils include:

- using the lowest recorded N value as a representative of the gravelly soil statum;
- recording N values for small-depth increments to assess the effect of gravel clasts as a basis for rejection or acceptance of the N value or to infer the N value for the finer-grained matrix of the gravelly deposit;
- or to use a large scale penetration test such as the Becker Hammer Drill, adjust the N values from the Becker test using established relationships to the SPT N values, and then using the adjusted N values in the liquefaction evaluation as for sand.

The quantitative liquefaction analysis performed for this study was complicated by the gravel component of many of the soils. Many of the N values from the gravelly sand strata are suspected of being too high, for the reasons discussed above. They are likely to lead to overestimation of the density of the soil and, therefore, result in an underestimation of the liquefaction susceptibility. To overcome this problem, the computerized analysis was reinterpreted to account for the gravel content. The log of each borehole was compared to the liquefaction analysis to evaluate if the results of the analysis appeared to have been affected by N values that are too high due to the presence of gravel. Correlations were made between boreholes to identify potentially liquefiable units where the N values appeared to have been affected by gravel content with areas where the N values do not appear to have been affected by the soil gravel content and areas where the boreholes lacked N values, and, accordingly, where no liquefaction analyses were conducted.

LIQUEFACTION ZONES

Criteria for Zoning

The areas underlain by late Quaternary geologic units were included in liquefaction zones using the criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the California State Mining and Geology Board (in press). Under those criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historic earthquakes.

2. All areas of uncompacted fills containing liquefaction susceptible material that are saturated, nearly saturated, or may be expected to become saturated.

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable.

4. Areas where existing geotechnical data are insufficient.

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historic high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (between 11,000 years and 15,000 years), where the M7.5-weighted peak acceleration that has a 10% probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historic high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria for liquefaction zoning in the Newhall Quadrangle is summarized below.

Areas of Past Liquefaction

Liquefaction resulting from the San Fernando earthquake of February 9, 1971 was not specifically identified in the study area, although damage was reported in the towns of Newhall and Saugus resulting from ground shaking on graded alluvium (Evans, 1975). Liquefaction-related ground settlement, abundant ground fractures, and sandblows resulting from the Northridge earthquake of January 17, 1994 were identified in Potrero Canyon in the Val Verde Quadrangle to the west of the study area (Rymer and others, 1995). Ground ruptures and other speculated liquefaction effects were also identified at numerous localities along the Santa Clara River (Stewart and others, 1994).

The Northridge earthquake also caused concentrations of structural and pipeline damage in Pico Canyon and the Newhall area which have been speculated to be potentially caused by liquefaction (Stewart and others, 1994) and (Hodgkinson and others, 1996). Although no conclusive evidence of liquefaction, such as sand boils, was identified in the areas where structural or pipeline damage occurred, pipe break descriptions do suggest that lateral ground movement had occurred. It is important to note, however, that the subsurface data collected for this investigation indicate the depth to ground water in Pico Canyon and the Newhall area is greater than 60 feet and, there, no significant confining beds to create shallow perched ground water were identified in this investigation. The areal extent of damage appears to too large to represent an area temporarily saturated by a flowing stream and, as the Los Angeles area had received less than 1 inch of rain since the beginning of the 1994-1995 water year prior to the earthquake (LACDPW, 1995), it is unlikely that enough water was available to saturate soils in the area damaged. Therefore, it appears the damage in these areas was not the result of liquefaction. These areas were not included in the liquefaction zones.

Artificial Fills

Large artificial fills are judged to be recent enough to have been placed using modern grading codes and, therefore, are assumed to have a low liquefaction susceptibility. The liquefaction susceptibility for areas underlain by artificial fill was based on the liquefaction susceptibility of the underlying natural geological unit.

Areas with Sufficient Existing Geotechnical Data

An area of the Santa Clara River between Castaic Junction and Bouquet Canyon and south to Magic Mountain Parkway (Highway 126) contains the largest number and highest concentration of boreholes with SPT field N values and liquefaction analyses in the study area. This area is underlain by late Holocene fluvial and alluvial deposits that are considered to have high liquefaction susceptibility based on the age and mode of deposition of these units. The ground-water table has been encountered at a depth of generally less than 20 feet in the main canyon and is inferred to be at a depth of less than 20 feet in the tributary canyons. Practically all of the analyses identify liquefiable sediments. The Santa Clara River and small tributary canyons between Castaic Junction and Bouquet Canyon were, therefore, included in the liquefaction zone.

Areas with Insufficient Existing Geotechnical Data

The small tributary canyons flanking the Santa Clara River between Castaic Junction and Dry Canyon and south to Magic Mountain Parkway (Highway 126) contained very few, unevenly distributed boreholes with SPT field N values and liquefaction analyses. This area is underlain by late Holocene fluvial and alluvial deposits that are considered to have high liquefaction susceptibility based on age and mode of deposition of the units. It is presumed that these sediments become saturated during periods of heavy precipitation and the ground-water table is inferred to be at a depth of less than 20 feet in the tributary canyons. Also, the anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, the small tributary canyons flanking the Santa Clara River Valley between Castaic Valley and Dry Canyon fall under Criteria item 4a (see above) and are, therefore, included within liquefaction zones.

Bouquet Canyon and Soledad Canyon both had only a few boreholes with SPT field N values and liquefaction analyses. The small tributary canyons in this area contain even fewer scattered boreholes with SPT field N values and liquefaction analyses. These canyons are underlain by late Holocene fluvial and alluvial geologic deposits that are considered to have high liquefaction susceptibility based on their age and mode of deposition. The water table has been measured at a depth of generally less than 20 feet in the main canyons and it is inferred to be at a depth of less than 20 feet in the tributary canyons. All of the available analyses identify liquefiable sediments. Also, the anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, Bouquet Canyon, Soledad Canyon and associated small tributaries fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the shallow ground water and on the overall liquefaction susceptibility of the near-surface geologic units, supplemented by the limited subsurface data.

Haskell Canyon and Dry Canyon both had no boreholes with SPT field N values and liquefaction analyses. These canyons are underlain by late Holocene fluvial and alluvial deposits that are considered to have high liquefaction susceptibility based on their age and mode of deposition. The measured depth to ground water in the southern half of the canyons is generally less than 30 or 40 feet. The inferred depth-to-ground water in the northern half of the canyons of 30 to 40 feet is based on correlation with the southern half of the canyons. Also, the anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, Haskell Canyon, Dry Canyon and associated small tributary canyons fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the measured and inferred shallow ground water and on the overall liquefaction susceptibility of the underlying geologic units.

San Francisquito Canyon had only a few boreholes with SPT field N values and liquefaction analyses in the southern portion of the canyon. The small tributary canyons in this area contain even fewer, scattered boreholes with SPT field N values and liquefaction analyses. These canyons are underlain by late Holocene fluvial and alluvial deposits that are considered to have high liquefaction susceptibility based on their age and mode of deposition. The measured depth to ground water in the southern half of the canyon is generally less than 20 feet. The inferred depth to ground water in the northern half of the canyon is 20 feet and is based on correlation with southern half of the canyon. All of the analyses identify liquefiable sediments. Also, the anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, San Francisquito Canyon and small tributary canyons fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the measured and inferred shallow ground water and on the overall liquefaction susceptibility.

Castaic Valley contains a moderate number of boreholes with SPT field N values and liquefaction analyses. The small tributary canyons in this area also contain a moderate number of unevenly distributed boreholes with SPT field N values and liquefaction analyses. This area is underlain by late Holocene fluvial and alluvial fan deposits that are considered to have high liquefaction susceptibility based on their age and mode of deposition. The ground-water table has been measured at a depth of generally less than 20 feet in the main canyon and inferred to be at a depth of less than 20 feet in the tributary canyons. Practically all of the analyses in the fan deposits along the margin of the valley floor identified liquefiable sediments; whereas, none of the analyses in the fluvial deposits underlying the valley floor identified liquefiable sediments. However, this situation is attributed to the high gravel content of the deposits beneath the valley floor, which has resulted in SPT field N values from the gravelly sand strata that are likely to be too high and lead to overestimation of the density of the soil and, therefore, underestimation of the liquefaction susceptibility of the deposit. Also, the anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, the portions of Castaic Valley and the small tributary canyons underlain by both the fluvial and fan deposits fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the measured and inferred shallow ground water, the overall liquefaction susceptibility of the underlying geologic units, the reevaluation of the liquefaction analyses to account for the gravel content, and supplemented by the limited subsurface data in the small tributary canyons.

South Fork Santa Clara River, south of the Magic Mountain Parkway (Highway 126 or Saugus-Ventura Road on the base map), contains only a few boreholes with SPT field N values and liquefaction analyses. The small tributary canyons in this area contain no boreholes with SPT field N values and liquefaction analyses. This area is underlain by late Holocene fluvial and alluvial deposits that are considered to have high liquefaction susceptibility based on their age and mode of deposition. The measured depth to ground water at the west end of Magic Mountain Parkway in the valley is about 15 feet and deepens toward the east to about 30 feet at the east end of that road at the eastern valley margin. Ground water deepens toward the south, reaching depths of about 70 to 100 feet at the confluence of Pico Canyon, Gavin Canyon, Newhall Creek Valley, and Placerita Canyon. Also, the anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, the portions of the

South Fork Santa Clara River with depths to ground water of less than 40 feet and the small tributary canyons fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the measured shallow ground-water depth and on the overall liquefaction susceptibility of the underlying geologic units, supplemented by the limited subsurface data.

Pico Canyon contains only a few boreholes with SPT field N values and liquefaction analyses. The small tributary canyons in this area contain no boreholes with SPT field N values and liquefaction analyses. This area is underlain by late Holocene fluvial and alluvial deposits that are considered to have high liquefaction susceptibility based on their age and mode of deposition. Ground water in most of Pico Canyon is 55 to 75 feet deep; in the tributary canyons and the western end of the canyon ground water is interpreted to be at 20 or 30 feet. Also, the anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, the western end and tributary canyons of Pico Canyon fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the interpreted shallow ground water and on the overall liquefaction susceptibility of the underlying geologic units, supplemented by the limited subsurface data.

Placerita Canyon or its small tributary canyons contains no borehole data with SPT field N values or liquefaction analyses. Ground water in Placerita Canyon is deeper than 50 feet west of the mouth of Quigley Canyon. To the east of the junction with Quigley Canyon ground water shallows to 30 feet at the eastern edge of the Newhall Quadrangle and in Quigley Canyon, the depth is interpreted to be 40 feet or less. Also, the anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, an approximately 1,800-foot stretch of Placerita Canyon near the eastern boundary of the Newhall Quadrangle, where the depth to ground water is less than 40 feet, and Quigley Canyon both fall under Criteria item 4a (see above) and were included in the liquefaction zone based primarily on the interpreted shallow ground water and on the overall liquefaction susceptibility of the underlying geologic units. Placerita Canyon west of Quigley Canyon was not included in the liquefaction zone based primarily on the measured depths of the ground water.

Gavin Canyon (not labeled on the map), through which Interstate Highway 5 enters the Newhall area from the south and Newhall Creek Valley contain only a few boreholes with SPT field N values and liquefaction analyses. The small tributary canyons in this area and the unnamed valley east of Gavin Canyon contain no boreholes with SPT field N values and liquefaction analyses. The ground-water table in Gavin Canyon is less than 40 feet deep at the southern edge of the study area and deepens toward the north to 50 feet at the canyon mouth. The depth to ground water in the Newhall Creek Valley is greater than 75 feet. Also, the anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, that portion of Gavin Canyon with a depth to ground water of less than 40 feet falls under Criteria item 4a (see above) and was included in the liquefaction zone based primarily on the interpreted shallow ground water and on the overall liquefaction susceptibility of the underlying geologic units. Newhall Creek Valley and the unnamed valley east of Gavin Canyon was not included in the liquefaction zone based primarily on the measured deep ground water.

Potrero Canyon and the unnamed canyon just to the north contain no boreholes with SPT field N values and liquefaction analyses. The depth to ground water in Potrero Canyon and the unnamed canyon just to the north was interpreted as 25 feet. Liquefaction-related ground deformation, ground fracturing, and sandblows resulting from Northridge earthquake of January 17, 1994 occurred in Potrero Canyon (Rymer and others, 1995). Also, the anticipated PGA having a 10% probability of being exceeded in 50 years is greater than 0.1g. As a result, Potrero Canyon and the unnamed canyon just to the north were included in the liquefaction zone based primarily on the occurrence of surface manifestations of liquefaction in Potrero Canyon triggered by the Northridge earthquake, the shallowness of the ground water, and on the overall liquefaction susceptibility of the underlying geologic units.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

Earthquake-Induced Landslide Zones in the Newhall 7.5-Minute Quadrangle, Los Angeles County, California

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PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/pubs/sp/117/).

This evaluation report summarizes seismic hazard zone mapping for earthquake-induced landslides in the Newhall 7.5-minute Quadrangle (scale 1:24,000). This section and Section 1 addressing liquefaction, are part of a series that will summarize development of similar hazard zone maps in the state (Smith, 1996). Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

BACKGROUND

Landslides triggered by earthquakes have historically been a major cause of earthquake damage. Landslides triggered by the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes were responsible for destroying or damaging numerous homes and other structures, blocking major transportation corridors, and damaging various types of life-line infrastructure. Areas that are most susceptible to earthquake-induced landslides are steep slopes in poorly cemented or highly fractured rocks, and loose soils, and on or adjacent to existing landslide deposits. These geologic and terrain conditions exist in many parts of California, most notably in hilly areas already developed or currently undergoing development. In addition, the opportunity for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region, which includes the Newhall Quadrangle.

SCOPE AND LIMITATIONS

The methodology used to make this map is based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient. These data are gathered primarily from a variety of outside sources; thus the quality of the data is variable. Although the selection of data used in this evaluation was rigorous, the State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data gathered from outside sources.

Earthquake-induced landslide zone maps are intended to prompt more detailed, site-specific geotechnical investigations as required by the Seismic Hazards Mapping Act (Public Resources Code, Chapter 7.8, Division 2). As such, these zone maps identify areas where the potential for earthquake-induced landslides is relatively high. Earthquake-generated ground failures that are not addressed by this map include those associated with ridge-top spreading and shattered ridges. No attempt has been made to map potential run-out areas of triggered landslides. It is possible that such run-out areas may extend beyond the zone boundaries. The potential for ground failure resulting from liquefaction-induced lateral spreading of alluvial materials, considered by some to be a form of landsliding, is not specifically addressed by the earthquake-induced landslide zone or this report. See Section 1, Liquefaction Evaluation Report for the Newhall Quadrangle, for more information on the delineation of liquefaction zones.

Information developed in the study is presented in two parts: physiographic, and geologic conditions in PART I, and ground shaking opportunity, landslide hazard potential and zoning evaluations in PART II.

PART I

STUDY AREA LOCATION AND PHYSIOGRAPHY

The Newhall Quadrangle covers approximately 62 square miles of land in west-central Los Angeles County. The center of the quadrangle lies about 30 miles northwest of the Los Angeles Civic Center. The City of Santa Clarita, which incorporates the communities of Newhall, Saugus, Valencia, and Canyon Country, covers the southeastern and east central parts of the quadrangle. The remainder of the area is comprised of unincorporated county land. A small part of the northeastern corner of the map lies within the Angeles National Forest. The primary transportation routes follow the valleys of the Santa Clara River and its tributaries. Access is provided from the north and the south via Interstate Highway 5, from the east via Soledad Canyon Road and Bouquet Canyon Road, and from the west via State Highway 126.

A variety of mountainous and lowland terrains characterizes the physiography of the quadrangle. The deeply dissected, mountainous topography that separates the major canyons includes: in the southwest quarter, portions of the northern Santa Susana Mountains; in the southeastern corner, a small northwesternmost extension of the San Gabriel Mountains; and, north of the Santa Clara River Valley is a region of rugged, chaparral-covered rocky terrain.

The Santa Clara River flows across the center of the quadrangle from east to west. Major tributaries include: the South Fork of the Santa Clara River along with its branches, Newhall Creek and Placerita Creek, which joins the main stream near Bouquet Junction; Castaic Creek, which joins the river near Castaic Junction; and the unnamed streams that flow southward into the Santa Clara River from Bouquet, Dry, and San Francisquito canyons.

Residential and commercial development has replaced agricultural and grazing land uses within the area in recent decades. Modern development is characterized by mass grading of the hillside areas at a large scale, especially north of the Santa Clara River and west of Interstate 5. The remainder of the area is largely unoccupied, although oil fields, agricultural activities, small ranches, and parklands are scattered across the quadrangle.

GEOLOGIC CONDITIONS

Surface and Bedrock Geology

For the Newhall Quadrangle, a recently compiled geologic map was obtained from the U.S. Geological Survey (USGS) in digital form (Yerkes and Campbell, 1995). This map was modified to reflect the most recent mapping in the area. In the field, observations were made of exposures, aspects of weathering, and general surface expression of the geologic units. In addition, the relation of the various geologic units to development and abundance of slope failures was noted.

The oldest geologic unit mapped is the upper Miocene Mint Canyon Formation (map symbol Tmc, Yerkes and Campbell, 1995), which crops out mainly in the northeastern corner of the map area. The nonmarine Mint Canyon Formation consists of well-bedded interlayered conglomeratic sandstone, claystone, and siltstone of fluvial and lacustrine (Tmcl) origin. Overlying the Mint Canyon Formation in the northeast corner of the map area is the upper Miocene Castaic Formation (Tcs), which consists of shallow marine sandstone and shale distinguishable by the large variety of mollusk species from the upper Miocene. Coevally deposited with the Castaic Formation, the upper Miocene to lower Pliocene Towsley Formation (Tws and Twc), consisting of interbedded marine siltstone, sandstone, and conglomerate, crops out in the southwestern corner of the map area.

Plio-Pleistocene rock units in the Newhall Quadrangle include the Pico and Saugus formations. The Pico Formation consists of marine siltstone, sandstone, and pebbly sandstone (Qtp, Qtps, and Qtpc), and is exposed in the southwest corner of the map area. The Saugus Formation, which is the dominant rock unit exposed in the area, overlies the Pico Formation and is composed of interbedded nonmarine sandstone, siltstone, and pebble-cobble conglomerate (Qs). In the northern half of the map area, the Saugus Formation has been divided into subunits wherein conglomerate beds contain either clasts of Mesozoic-age (?) Pelona Schist (Qsp) or clasts of shale from the Paleocene San Francisquito Formation (Qss).

Older Quaternary deposits such as older fanglomerate (Qfo), older terrace deposits (Qto), Pacoima Formation (Qpa), and terrace deposits (Qt) consist of poorly consolidated interbeds of sand, silt, and gravel. Terrace deposits unconformably overlie the Saugus Formation in the southern half of the map, and are the second most widespread unit (excluding younger alluvium) in the quadrangle.

Younger Quaternary surficial deposits cover the floor and margins of the valley formed by the Santa Clara River and extend up into the canyons in the surrounding hills and mountains. They consist of slope wash (Qsw), landslide deposits (Qls), older alluvium (Qao), pond deposits (Ql), and younger alluvium (Qal, Qal1, and Qal2). Modern man-made fill (af) is also mapped in some areas. A more detailed discussion of the Quaternary deposits in the Newhall Quadrangle can be found in Section 1.

Geologic Material Strength

To evaluate the stability of geologic materials under earthquake conditions, they first must be ranked based on their overall shear strength. Shear strength data for the rock units identified on the geologic map were obtained from a variety of sources (see Appendix A). The primary source for rock shear strength measurements is geotechnical reports prepared by consultants on file with the local government permitting departments. Geotechnical and engineering geologic reports contained in Environmental Impact Reports and Hospital Review Project files at DMG are additional sources. Where shear strength information was lacking for certain rock units within the Newhall Quadrangle itself, it was collected from adjacent areas. The locations of rock and soil samples taken for shear testing are shown on Plate 2.1.

Shear strength data gathered from the above source were compiled for each mapped geologic unit, and subdivided for fine-grained and coarse-grained lithologies if appropriate. Geologic units were grouped on the basis of average angle of internal friction (average f) and lithologic character. When available, shear tests from adjacent quadrangles were used to augment data for geologic formations that had little or no shear test information.

To subdivide mapped geologic formations that have both fine-grained and coarse-grained lithologies, we assumed that where stratigraphic bedding dips into a slope (favorable bedding) the coarse-grained material strength dominates, and where bedding dips out of a slope (adverse bedding) the fine-grained material strength dominates. We then used structural information from the geologic map (see "Structural Geology") and terrain data in the form of slope gradient and aspect, to identify areas with a high potential for containing adverse bedding conditions. These areas, located on the map, were then used to modify the geologic material-strength map to reflect the anticipated lower shear strength for the fine-grained materials.

The results of the grouping of geologic materials in the Newhall Quadrangle are in Tables 2.1 and 2.2.

NEWHALL QUADRANGLE
SHEAR STRENGTH GROUPS

	Formation Name	Number Tests	Mean/Median Phi (deg)	Mean/Median Group Phi (deg)	Mean/Median Group C (psf)	No Data: Similar Lithology	Phi Values Used in Stability Analyses
GROUP 1	Tmc(fbc)*	8	34/34	36/37	360/310	Tws(fbc)*	36
	Tcs(fbc)	7	39/40			Tmcl(fbc)	
						Twc(fbc)	
GROUP 2	QTp(fbc)*	4	32/33	31/31	360/300	QTps(fbc)	31
	Qs(fbc)*	61	31/32			QTpc(fbc)	
	Qt	25	32/34			Qsp(fbc)	
	Qao	9	30/31			Qss(fbc)	
	Qal	56	30/30			Qfo, Qto	
	af	9	31/28			Qpa, Qsw	
						Qal1, Qal2	
GROUP 3	Tmc(abc)*	13	27/28	28/28	680/600	Tmcl(abc)	28
	Tcs(abc)	6	30/31			Twc(abc)	
	Tws(abc)*	1	29/29			QTps(abc)	
	QTp(abc)*	3	28/28			Qsp(abc)	
	Qs(abc)*	6	30/29			Qss(abc)	
GROUP 4	Qls	7	25/25	25/25	250/250		18**

abc = adverse bedding condition, fine-grained material strength
fbc = favorable bedding condition, coarse-grained material strength
* subunits of these formations have been combined
** lowest calculated phi value was accepted as representative phi value for landslides

Table 2.1. Summary of the shear strength statistics for the Newhall Quadrangle.

SHEAR STRENGTH GROUPS FOR THE NEWHALL QUADRANGLE			
GROUP 1	GROUP 2	GROUP 3	GROUP 4
Tcs(fbc)	QTp(fbc)	Tcs(abc)	Qls
Tmc(fbc)	QTps(fbc)	Tmc(abc)	
Tmcl(fbc)	QTpc(fbc)	Tmcl(abc)	
Tws(fbc)	Qs(fbc)	Tws(abc)	
Twc(fbc)	Qsp(fbc)	Twc(abc)	
	Qss(fbc)	QTp(abc)	
	Qfo	QTps(abc)	
	Qto	QTpc(abc)	
	Qpa	Qs(abc)	
	Qt	Qsp(abc)	
	Qao	Qss(abc)	
	Qsw		
	Qal		
	Qal1		
	Qal2		
	af		

Table 2.2. Summary of the shear strength groups for the Newhall Quadrangle.

Structural Geology

The San Gabriel Fault, which transects the Newhall Quadrangle from northwest to southeast, is the dominant regional structure in the area. Most faults and fold axes, as well as the strike of bedding of the pre-Quaternary rock units, trend subparallel to the strike of the San Gabriel Fault. Steeply dipping bedrock (> 45º) exists primarily in the southwest corner of the map and adjacent to the San Gabriel Fault zone.

Accompanying the digital geologic map (Yerkes and Campbell, 1995) were digital files of associated geologic structural data, including bedding and foliation attitudes (strike and dip) and fold axes. We used the structural geologic information provided with the digital geologic map (Yerkes and Campbell, 1995) and from Treiman (1986; 1987) to categorize areas of common stratigraphic dip direction and magnitude, similar to the method presented by Brabb (1983). The dip direction category was compared to the slope aspect (direction) category and, if the same, the dip magnitude and slope gradient categories were compared. If the dip magnitude category was less than or equal to the slope gradient category, and the bedding dip was greater than 25% (4:1 slope), the area was marked as a potential adverse bedding area. This information was then used to subdivide mapped geologic units into areas where fine-grained and coarse-grained strengths would be used.

Landslide Inventory

The evaluation of earthquake-induced landsliding requires an up-to-date and complete picture of the previous occurrence of landsliding. An inventory of the existing landslides in the Newhall Quadrangle was prepared by using previous work (Treiman, 1986;1987). The completed hand-drawn landslide map was scanned, digitized and the database was attributed with landslide information on confidence of interpretation (definite, probable, or questionable) and other properties, such as activity, thickness, and associated geologic unit(s). Aerial photos (see Air Photos in References) were used to aid in attributing the landslide table that is associated with the map. All landslides shown on the digital geologic map (Yerkes and Campbell, 1995) were verified or re-mapped during preparation of the inventory maps. To keep the landslide inventories of consistent quality, all landslides originally depicted on the digitized geologic map were deleted and only those included in the DMG inventory were incorporated into the hazard-evaluation process. A version of this landslide inventory is included with Plate 2.1.

PART II

EARTHQUAKE-INDUCED LANDSLIDE GROUND SHAKING OPPORTUNITY

Design Strong-Motion Record

The Newmark analysis used in delineating the earthquake-induced landslide zones requires the selection of a design earthquake strong-motion record. For the Newhall Quadrangle, the selection was based on an estimation of probabilistic ground motion parameters for modal magnitude, modal distance, and peak ground acceleration (PGA). The parameters were estimated from maps prepared by DMG for a 10% probability of being exceeded in 50 years (Petersen and others, 1996; Cramer and Petersen, 1996). The parameters used in the record selection are:

Modal Magnitude:	6.6 to 7.7
Modal Distance:	2.5 to 22.0 km
PGA:	0.5 to 1.0 g

Based on the range in modal magnitude and distance, two potential strong-motion records of different source magnitudes and distances were evaluated to determine the greatest potential Newmark displacements (see “Displacement Calculation” section) in the Newhall Quadrangle: 1) a simulated San Andreas fault event of 8.0 Mw at 30 km (Paul Sommerville, personal communication), and 2) the USC Station #14 record (Trifunac and others, 1994) from the 1994 Northridge earthquake of 6.7 Mw at 8.5 km.

We determined that the smaller, near-field event (Northridge earthquake) produced greater Newmark displacements (explained below) and, therefore, would provide a better, conservative evaluation. The selected strong-motion record had a peak ground acceleration of 0.59 g and was not scaled or otherwise modified prior to analysis.

Displacement Calculation

To develop a relationship between the yield acceleration (a_y; defined as the horizontal ground acceleration required to cause the factor of safety to equal 1.0) and Newmark displacements, the design strong-motion record was integrated twice for a given a_y to find the corresponding displacement, and the process repeated for a range of a_y (Jibson, 1993). The resulting curve in Figure 2.1 represents the full spectrum of displacements that can be expected for any combination of geologic material strength and slope angle, as represented by the yield acceleration. We used displacements of 30, 15 and 5 cm as criteria for rating levels of earthquake shaking damage on the basis of the work of Youd (1980), Wilson and Keefer (1983), and the DMG pilot study for earthquake-induced landslides (McCrink and Real, 1996). Applied to the curve in Figure 2.1, these displacements correspond to yield accelerations of 0.076, 0.129 and 0.232g. These yield acceleration values were then used as earthquake-induced landslide susceptibility criteria in the stability analyses.

EARTHQUAKE-INDUCED LANDSLIDE HAZARD POTENTIAL

Terrain Data

The calculation of slope gradient is an essential part of the evaluation of slope stability under earthquake conditions. To calculate slope gradient for the terrain within the Newhall Quadrangle, a Level 2 digital elevation model (DEM) was obtained from the USGS (U.S. Geological Survey, 1993). This DEM, which was prepared from the topographic contours constructed in 1952 for the 7.5-minute quadrangle map, has a 10-m horizontal resolution and a 7.5-m vertical accuracy. A program that adds a pixel to the edges of the DEM was run twice to avoid the loss of data at the quadrangle edges when the slope calculations were performed.

To update the terrain data, areas that have recently undergone large-scale grading in the hilly portions of the Newhall Quadrangle were identified on aerial photography flown in the winter and spring of 1994 (see Plate 2.1). Terrain data for these areas were obtained from an airborne interferometric radar (TOPSAR) DEM flown and processed in August 1994 by NASA's Jet Propulsion Laboratory (JPL), and reprocessed by Calgis, Inc. (GeoSAR Consortium, 1995 and 1996). These terrain data were also smoothed prior to analysis. This corrected terrain data was digitally merged with the USGS DEM.

A slope map was made from the corrected DEM using a third-order, finite difference, center-weighted algorithm (Horn, 1981). The original USGS DEM was then used to make a slope-aspect map. The slope map was used first in conjunction with the aspect map and geologic structural data to identify areas of potential adverse bedding conditions, and then again with the

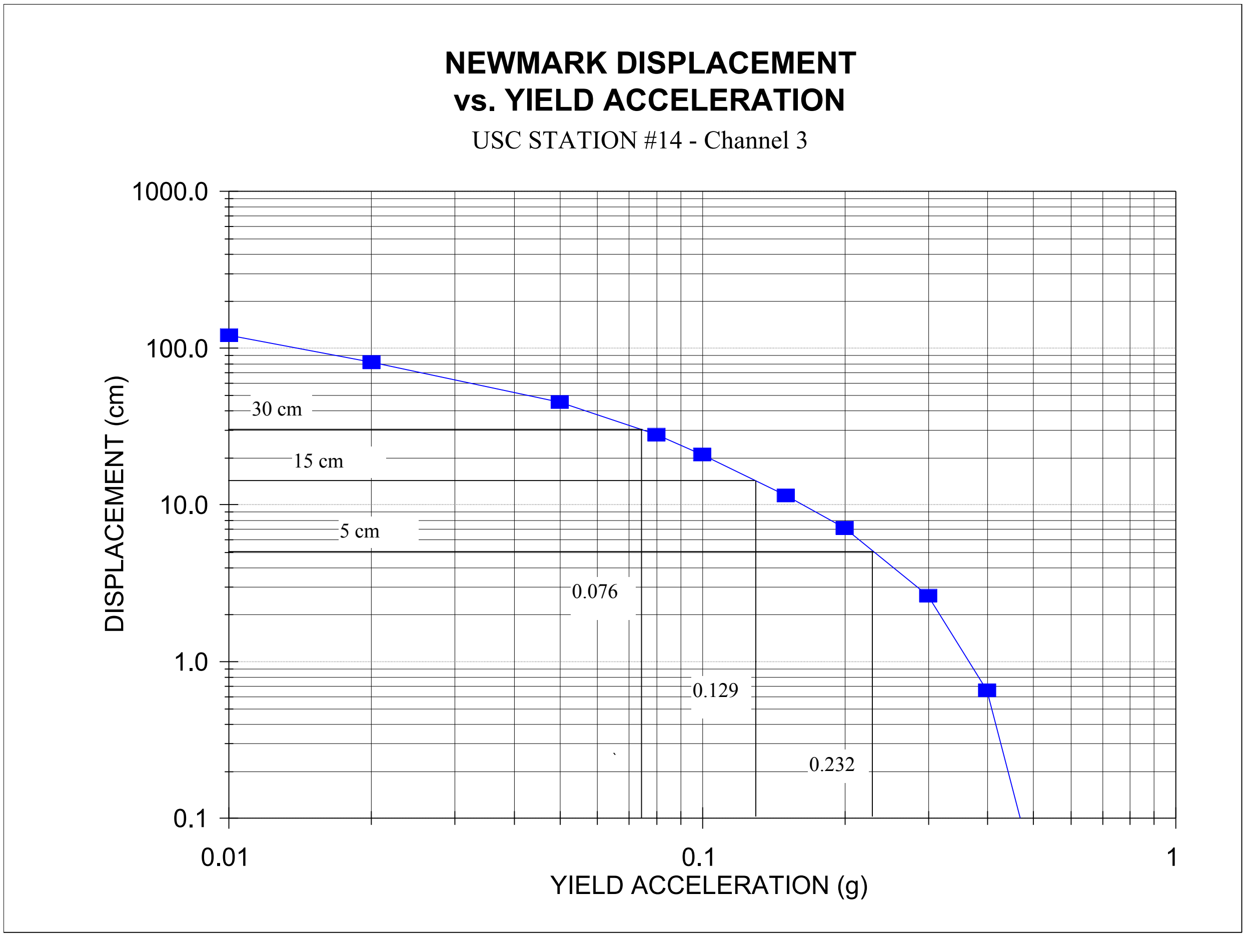

Figure 2.1. Yield acceleration vs. Newmark displacement for the the USC Station # 14 strong-motion record from the 17 January 1994 Northridge, California Earthquake.

geologic strength map in the preparation of the earthquake-induced landslide hazard potential map.

Stability Analysis

A slope stability analysis was performed for each geologic material strength group at slope increments of 1 degree. An infinite-slope failure model under unsaturated slope conditions was assumed. A factor of safety was calculated first, followed by the calculation of yield acceleration from Newmark's equation:

$$a_y = (FS - 1)g \sin \alpha$$

where FS is the Factor of Safety, g is the acceleration due to gravity, and α is the direction of movement of the slide mass, in degrees measured from the horizontal, when displacement is initiated (Newmark, 1965). For an infinite slope failure α is the same as the slope angle.

The yield acceleration calculated by Newmark's equations represents the susceptibility to earthquake-induced failure of each geologic material strength group for a range of slope gradients. The acceleration values were compared with the ground shaking opportunity, defined by Figure 2.1, to determine the earthquake-induced landslide hazard potential. Based on the susceptibility criteria described in Figure 2.1 above, if the calculated yield acceleration was less than 0.076 g, expected displacements could be greater than 30 cm, and a HIGH (H on Table 2.3) hazard potential was assigned. Likewise, if the calculated a_y fell between 0.076 and 0.129 g a MODERATE (M on Table 2.3) potential was assigned, between 0.13 and 0.232 a LOW (L on Table 2.3) potential was assigned, and if a_y were greater than 0.232 g a VERY LOW (VL on Table 2.3) potential was assigned.

Table 2.3 summarizes the results of the stability analyses. The earthquake-induced landslide hazard potential map was prepared by combining the geologic material-strength map and the slope map according to this table.

NEWHALL QUADRANGLE
HAZARD POTENTIAL MATRIX

SLOPE CATEGORY

Geologic Material Group	MEAN PHI	I 0-18	II 19-29	III 30-35	IV 36-45	V 46-51	VI 52-63	VII > 63 percent
1	36	VL	VL	VL	VL	L	M	H
2	31	VL	VL	VL	L	M	H	H
3	28	VL	VL	L	M	H	H	H
4	18	L	H	H	H	H	H	H

Table 2.3. Hazard potential matrix for earthquake-induced landslides in the Newhall Quadrangle. Shaded area indicates hazard potential levels included within the hazard zone.

EARTHQUAKE-INDUCED LANDSLIDE ZONE

Criteria for Zoning

Earthquake-induced landslide zones were delineated using criteria adopted by the California State Mining and Geology Board (1996). Under those criteria, earthquake-induced landslide zones are areas meeting one or both of the following:

4. Areas identified as having experienced landslide movement in the past (including all mappable landslide deposits and source areas), and, where possible, areas known to have experienced earthquake-induced landsliding during historic earthquakes.

5. Areas where geologic and geotechnical data and analyses indicate that the earth materials may be susceptible to earthquake-induced slope failure.

Existing Landslides

Studies of the types of landslides caused by earthquakes (Keefer, 1984) show that re-activation of the whole mass of deep-seated landslide deposits is rare. However, it has been observed that the steep scarps and toe areas of existing landslides, which formed as a result of previous landslide movement, are particularly susceptible to earthquake-induced slope failure. In addition, because they have been disrupted during landslide movement, landslide deposits are inferred to be weaker than coherent, undisturbed, adjacent source rocks. Finally, we felt that a long duration, San Andreas fault-type earthquake could be capable of initiating renewed movement in existing deep-seated landslide deposits. Therefore, all existing landslides identified in the inventory with a definite or probable confidence of interpretation were included in the hazard zone.

The February 9, 1971 San Fernando earthquake likely triggered numerous rockfalls and debris falls in the portion of the San Gabriel Mountains that extends into the southeastern corner of the Newhall Quadrangle (Evans, 1975). These shallow failures were only referred to in general descriptions of the effects of the event and have not been delineated on any maps. The 1994 Northridge earthquake also caused a number of relatively small, shallow slope failures in the Newhall Quadrangle (Harp and Jibson, 1995). Landslides attributed to the Northridge earthquake covered approximately 135 acres of land in the quadrangle, which is less than 1/2 of 1 percent of the total area covered by the map. Of the area covered by these Northridge earthquake landslides, 90% falls within the area of the hazard zone based on a computer comparison of the zone map and the Harp and Jibson (1995) inventory.

Geologic and Geotechnical Analysis

On the basis of a DMG pilot study (McCrink and Real, 1996) the earthquake-induced landslide zone includes all areas determined to lie within the High, Moderate and Low levels of hazard potential. Therefore, as shown in Table 2.3, geologic strength group 4 is always included in the zone (mapped landslides Qls); strength group 3 is in the zone for all slopes greater than 29%;

strength group 2 above 35%; and strength group 1 above 45%. This results in roughly 26% of the land in the Newhall Quadrangle lying within the hazard zone.

ACKNOWLEDGMENTS

The authors would like to thank the following individuals and organizations for their assistance in obtaining the data necessary to complete this project. Geologic material strength data were collected at the Los Angeles County Department of Public Works with the assistance of Robert Larsen, James Shuttleworth, Charles Nestle, and Dave Poplar. Digital terrain data and assistance were provided by Randy Jibson of the U.S. Geological Survey (USGS DEM), and Scott Hensley of JPL and Gerald Dildine and Chris Bohain of Calgis, Inc. (Radar DEM). Technical review of the methodology was provided by Bruce Clark, Randy Jibson, Robert Larsen, Scott Lindvall, and J. David Rogers, who are members of the State Mining and Geology Board's Seismic Hazards Mapping Act Advisory Committee Landslides Working Group. At DMG, special thanks to Bob Moskovitz, Teri McGuire, Scott Shepherd, and Barbara Wanish for their Geographic Information System operations support, and to Joy Arthur for designing and plotting the graphic displays associated with the hazard zone map and this report.

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APPENDIX A
SOURCE OF ROCK STRENGTH DATA

SOURCE	NUMBER OF TESTS SELECTED
Los Angeles County Department of Public Works	166
Geotechnical reports from environmental impact documents on file at DMG	49
Total number of tests used to characterize the units in the Newhall Quadrangle	215

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Newhall 7.5-Minute Quadrangle, Los Angeles County, California

By

Mark D. Petersen, Chris H. Cramer, Geoffrey A. Faneros, Charles R. Real, and Michael S. Reichle

California Department of Conservation
Division of Mines and Geology

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation, Division of Mines and Geology (DMG) to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (1997; also available on the Internet at http://www.consrv.ca.gov/dmg/pubs/sp/117/).

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included, are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5- minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the "Simple Prescribed Parameter Value" method (SPPV) described in the site investigation guidelines (California State Mining and Geology Board, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2, addressing liquefaction and earthquake-induced landslide hazards, constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on DMG's Internet homepage: http://www.consrv.ca.gov/dmg/shezp/

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the seismogenic sources as published in the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology, and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10% probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

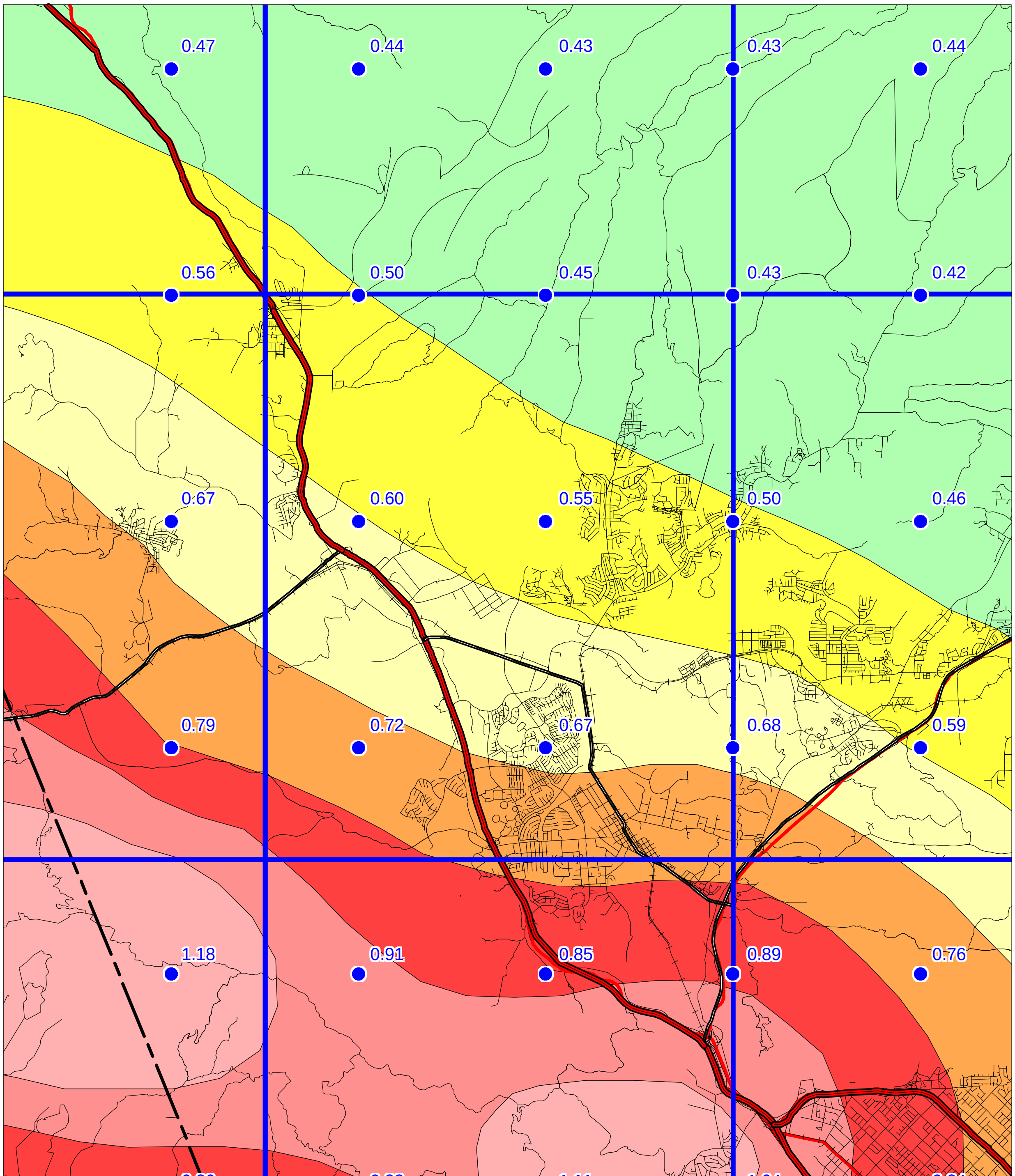
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10% probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight adjacent quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

NEWHALL 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map modified from MapInfo StreetWorks ©1998 MapInfo Corporation

0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

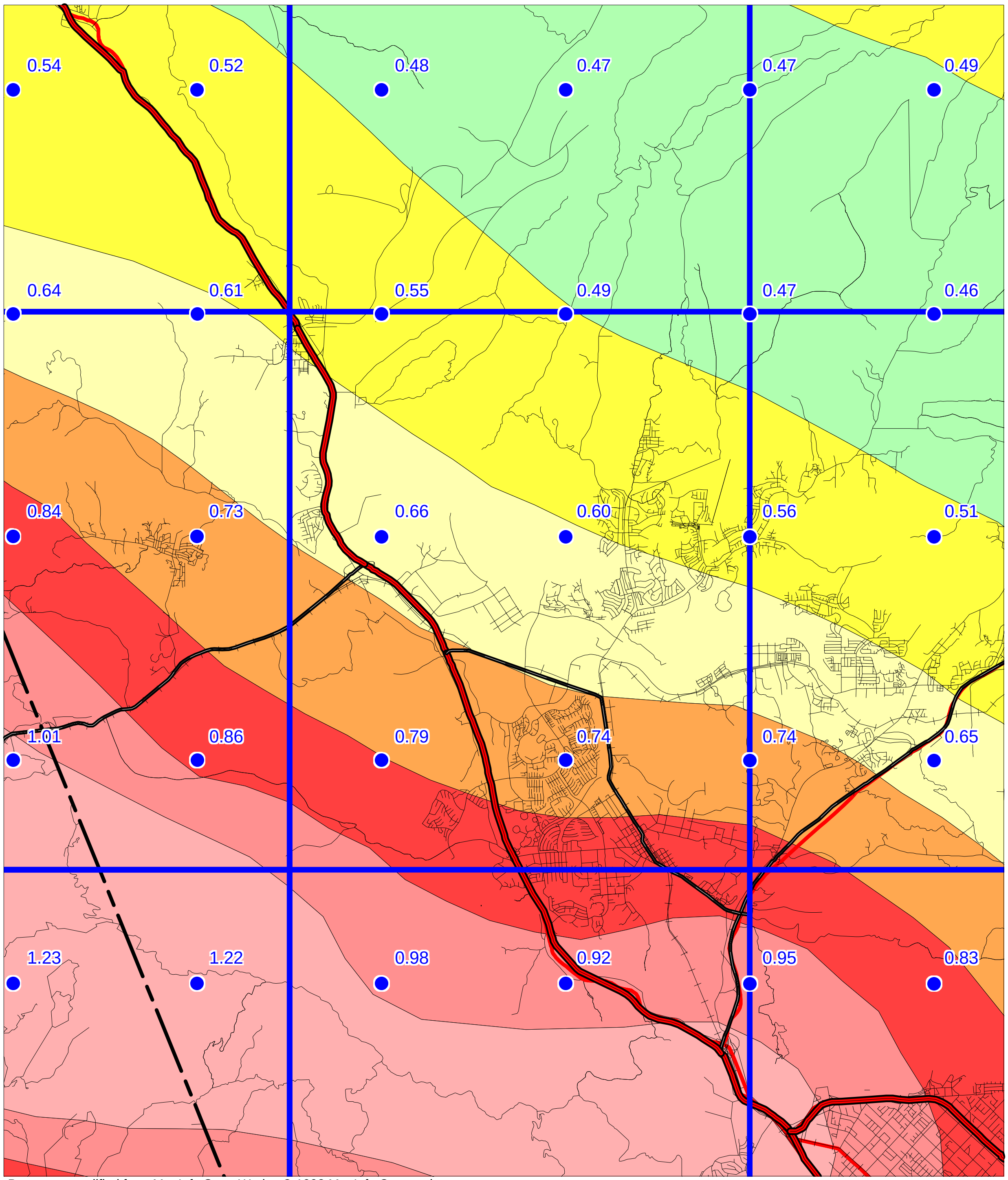
Figure 3.1

NEWHALL 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

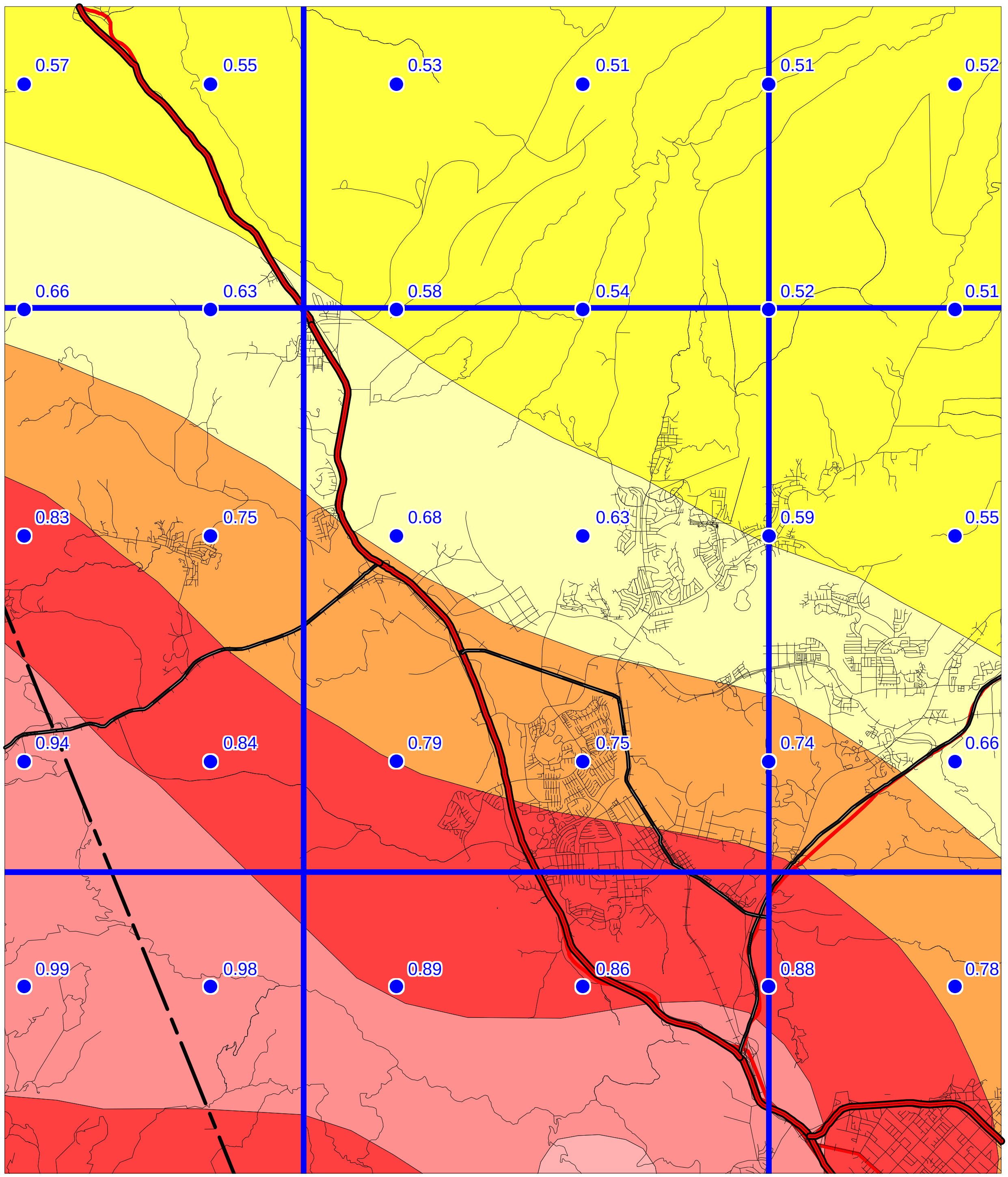
Figure 3.2

NEWHALL 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS



Base map modified from MapInfo Street Works ©1998 MapInfo Corporation

0 2.5 5

Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.3

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10% probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

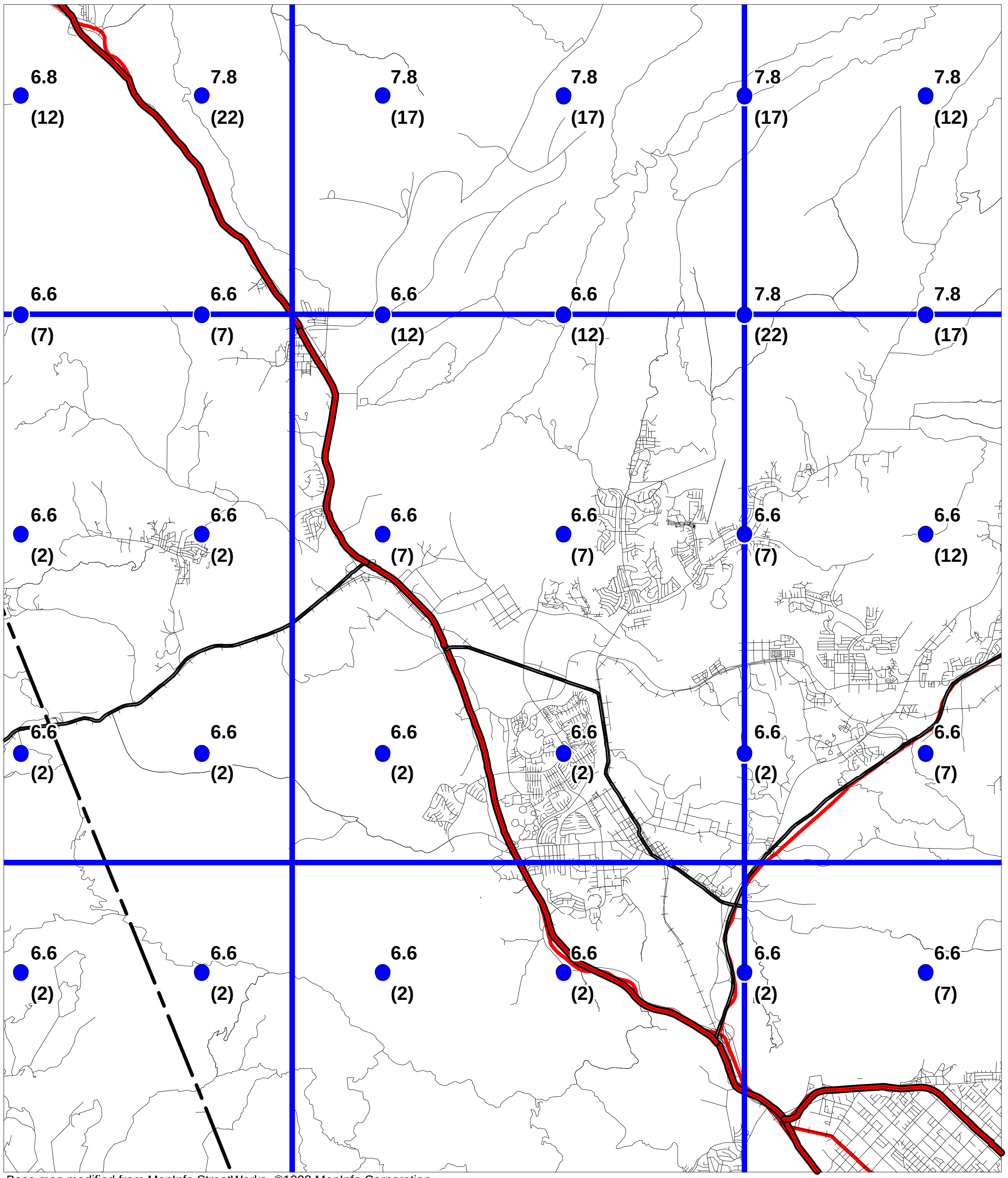
2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual

NEWHALL 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



0 2.5 5
Kilometers

Department of Conservation
Division of Mines and Geology

Figure 3.4

ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50% of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not previously been recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (California State Mining and Geology Board, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the "importance" or sensitivity of the proposed building with regard to occupant safety.

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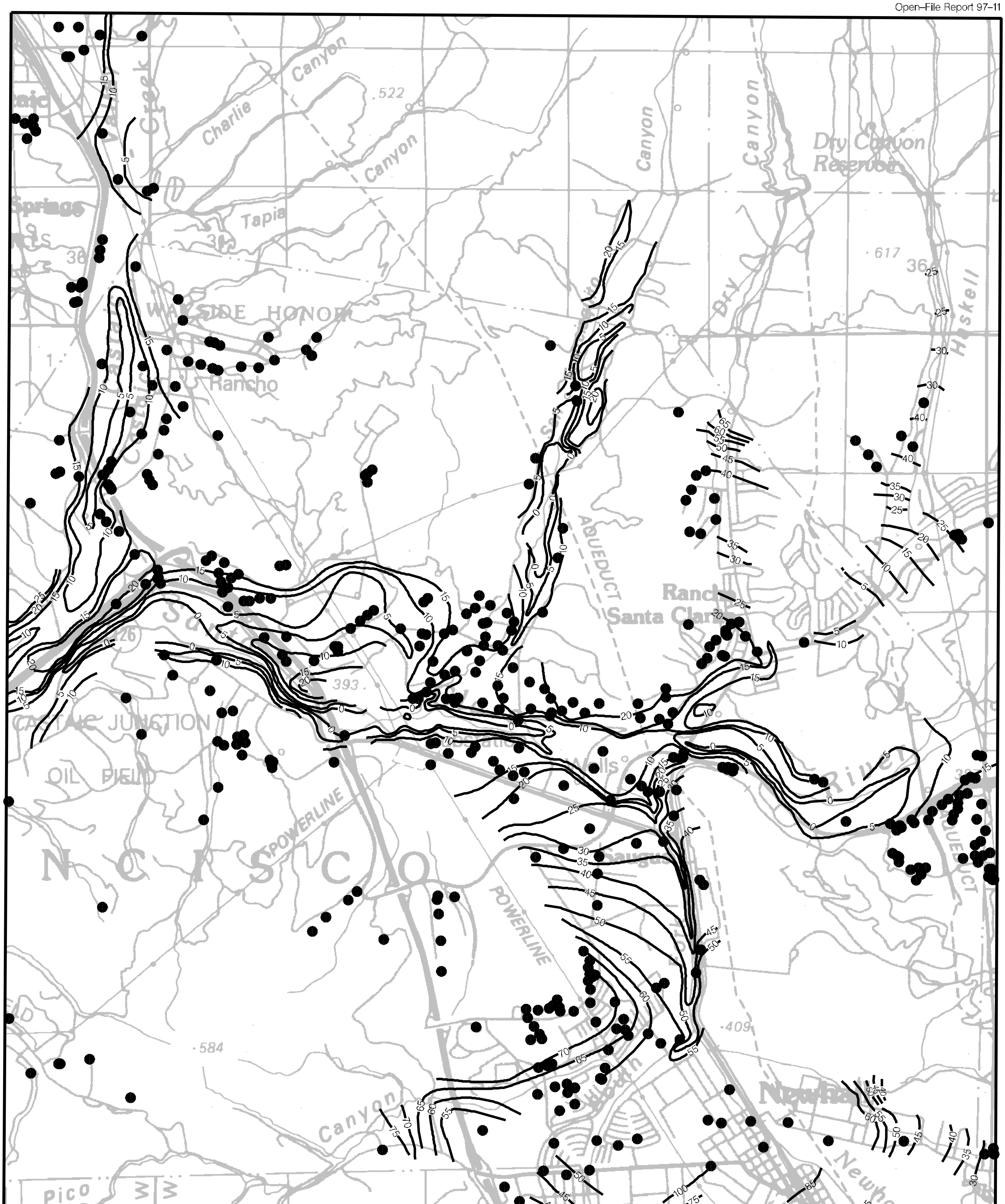
Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 1.1 Map depicting the portion of the Newhall quadrangle underlain by Qaternary alluvial and young fluvial sedimentary (flatland) deposits and artificial fill that are interpreted as being generally susceptible to liquefaction and were evaluated in this investigation.

ONE MILE

SCALE



Base map enlarged from U.S.G.S. 30 x 60–minute series

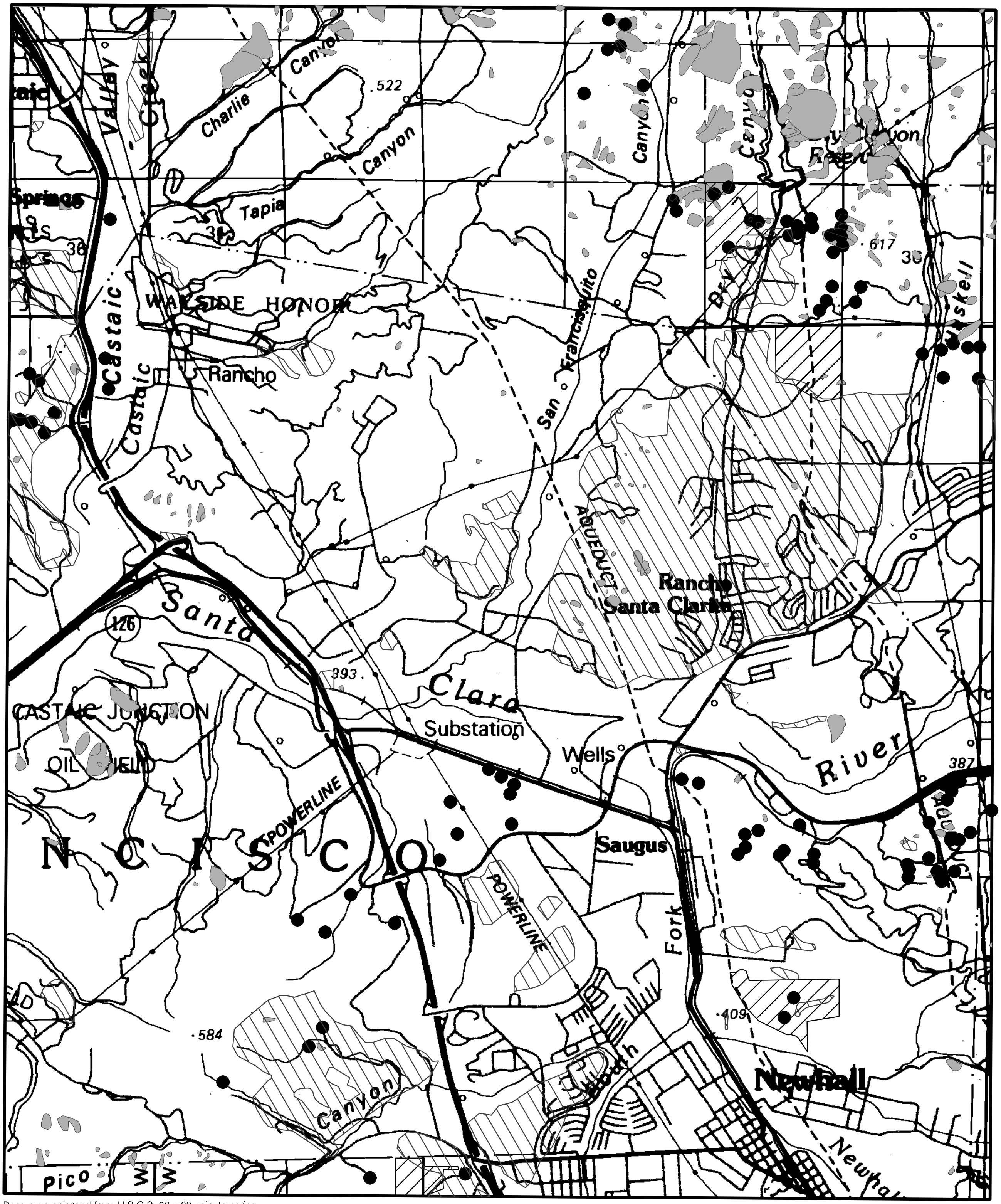
Plate 1.2 Historically Highest Ground Water Contours and Borehole Log Data Locations, Newhall Quadrangle.

● Borehole Site

30 Depth to ground water in feet

ONE MILE

SCALE



Base map enlarged from U.S.G.S. 30 x 60–minute series

Plate 2.1 Landslide Inventory, Shear Test Sample Locations, and Areas of Significant Grading, Newhall Quadrangle.

● Shear test sample location — Landslide — Area of significant grading — Tract report with multiple shear tests

ONE MILE

SCALE